ADVANCES IN STUDIES OF ELECTRODE KINETICS AND MASS TRANSPORT IN AMTEC CELLS

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ABSTRACT

Previous work reported from JPL has included characterization of electrode kinetics and alkali atom transport from electrodes including Mo, W, WRh_x, WPt_x(Mn), in sodium AMTEC cells and vapor exposure cells; and Mo in potassium vapor exposure cells. These studies were generally performed in cells with small area electrodes (about 1 to 5 cm^2), and device geometry had little effect on transport. Alkali diffusion coefficients through these electrodes have been characterized, and approximate surface diffusion coefficients derived in cases of activated transport. A basic model of electrode kinetic at the alkali metal vapor/ porous metal electrode/ alkali bet.a''-alumina solid electrolyte three phase boundary has been proposed which accounts for electrochemical reaction rates with a collision frequency near' the three phase boundary and tunneling from the porous electrode partially covered with adsorbed alkali metal atoms. The small electrode effect in AMTEC cells has been discussed in several papers, but quantitative investigations have described only the overall effect and the important contribution of electrolyte resistance. The quantitative characterization of transport losses in cells with large area electrodes has been limited to simulations of large area electrode effects, or characterization of transport losses from large area electrodes with significant longitudinal temperature gradients. This paper describes new investigations of electrochemical kinetics and transport, particular y with $WPt_{3.5}$ electrodes, including the influence of electrode size on the mass transport loss in the AMTEC cell. These electrodes posses excellent sodium transport properties making verification of device limitations on transport much more readily attained. The transport limitations were evaluated using four closely spaced 14.4 cm^2 electrodes at nearly constant temperature within a cylindrical multifoil heat shield at a distance of 0.75 cm from the electrodes on the surface of a 30 x 1.5 cm sodium beta"-alumina solid electrolyte (Na-BASE) tube; and characterizing the transport losses in single electrodes, all possible pairs and triplets of electrodes, and all four electrodes operated simultaneous y. The faradaic resistance, comprised of losses due to electrode kinetics and pressure gradients, was evaluated using ac impedance at a series of potentials typically within 0.7 V of open circuit. The area averaged faradaic loss increased substantial y with number of electrodes operated in parallel. The thermal gradients in this cell were also thoroughly characterized' using internal and external thermocouples on the Na-BASE tube and pyrometry utilizing two shutters and a small hole in the multifoil heat shield. The thermal characterization, to be reported in detail elsewhere, makes possible more precise evaluation of the temperature dependence of kinetics and transport in these electrodes from 830K to over 1200K. $WPt_{3.5}$ electrodes are possibly the best candidate electrodes for AMTEC modules for moderate length planetary exploration missions where wide temperature range performance is required. The research described in this paper was performed by the Jet Propulsion Laboratory, California Institute of Technology, and was supported by the National Aeronautics and Space Administration, and the Air Force Phillips Laboratory. The authors also thank Dr. Joseph Kummer for helpful discussions.